AI and Machine Leanring HW-09

12111820 黄国靖

Introduction

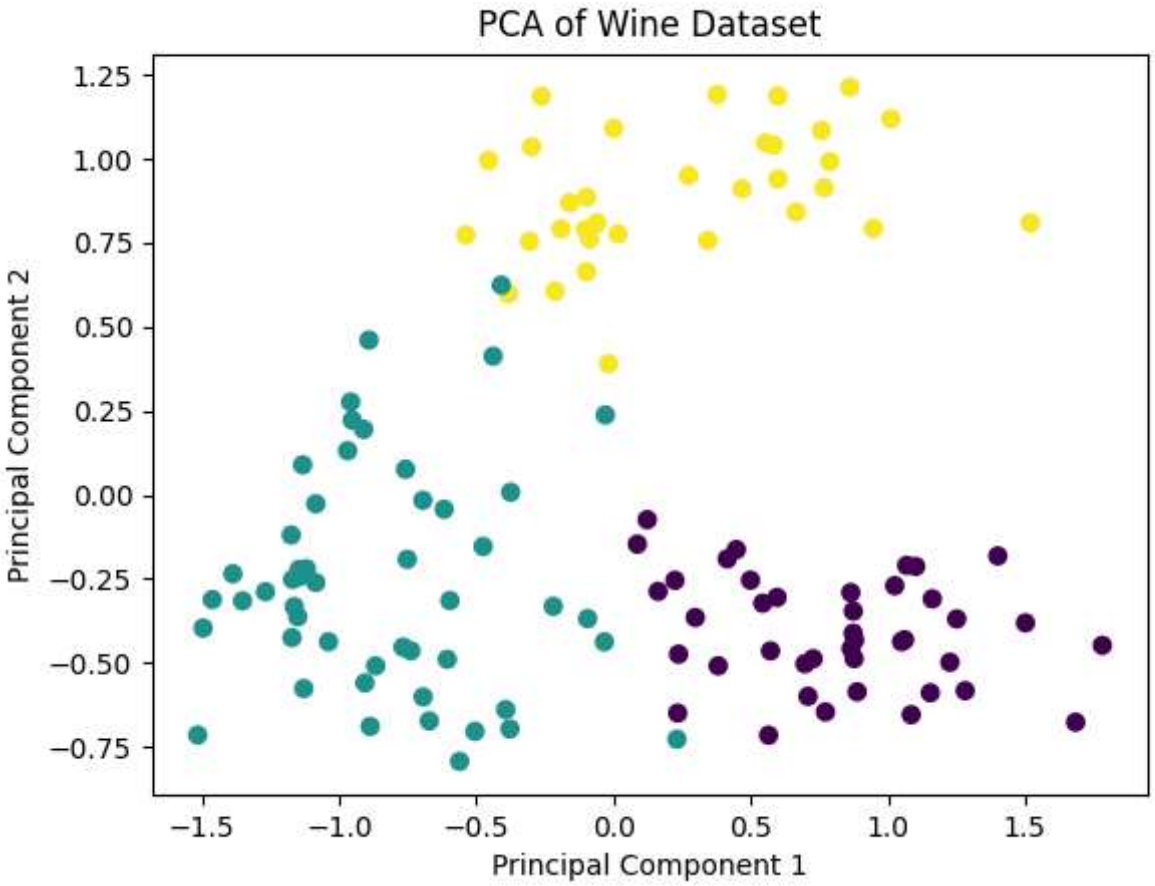
In this assignment, you will explore dimensionality reduction using Principal Component Analysis (PCA) and simple Autoencoders (both linear and non-linear) on the Wine dataset. You will implement these algorithms in Python using NumPy and compare their reconstruction errors.

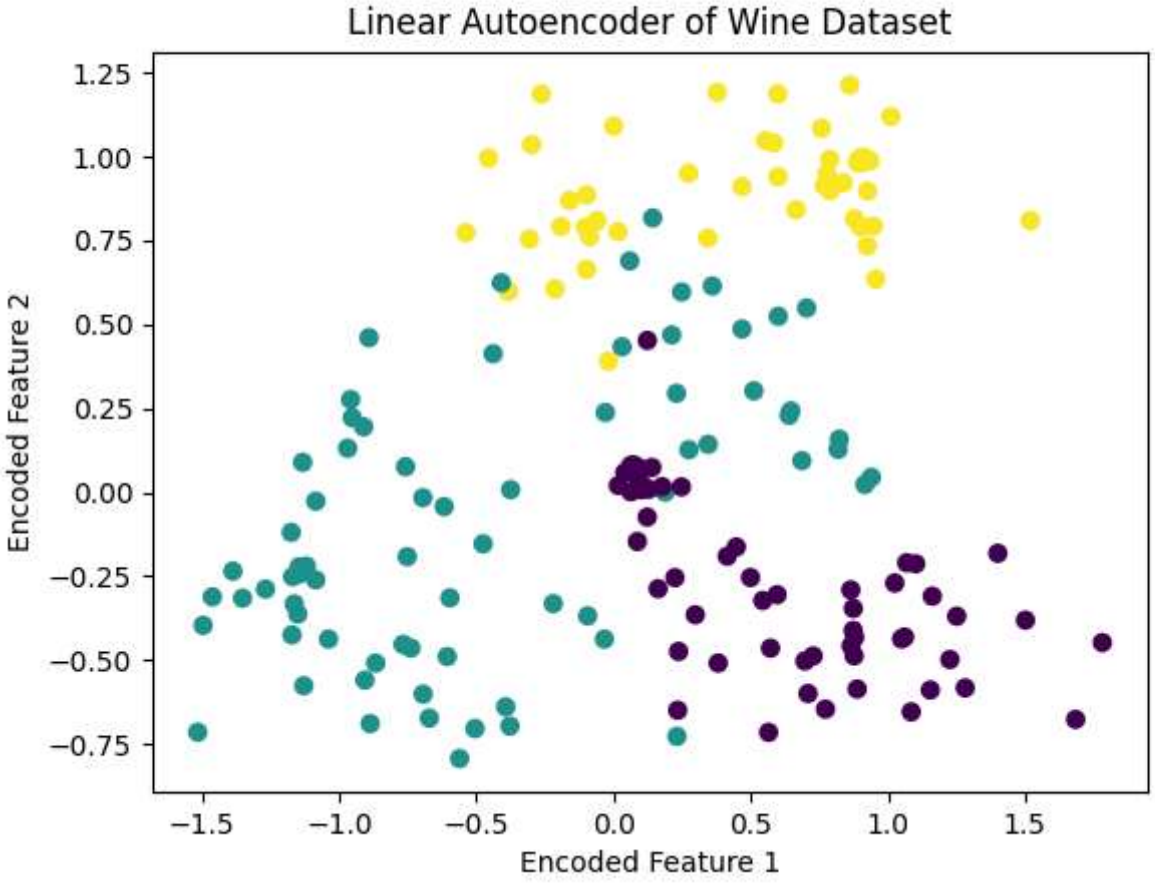
1. Implement PCA:
    - Write a Python function using NumPy to perform PCA on the Wine dataset.
    - Consider only the first two principal components for dimensionality reduction.
    - Reconstruct the data using these two principal components.
    - Visualize the principal compoenents in the two dimensional space.
2. Train a Linear Autoencoder:
    - Implement a linear autoencoder using a neural network design.
    - Train the autoencoder on the Wine dataset.
    - Reconstruct the data using the trained autoencoder.
    - Visual lize the output of the encoder; Calculate and report the reconstruction error.
3. Train a Non-linear Autoencoder:
    - Implement a non-linear autoencoder with at least one hidden layer that uses an activation function (e.g., ReLU).
    - Train the non-linear autoencoder on the Wine dataset.
    - Reconstruct the data using the trained autoencoder.
    - Visual lize the output of the encoder; Calculate and report the reconstruction error.
4. Comparison and Analysis:
    - Compare the reconstruction errors of the PCA, linear autoencoder, and non-linear autoencoder.
    - Analyze the results and discuss which method provides the best reconstruction accuracy and why.

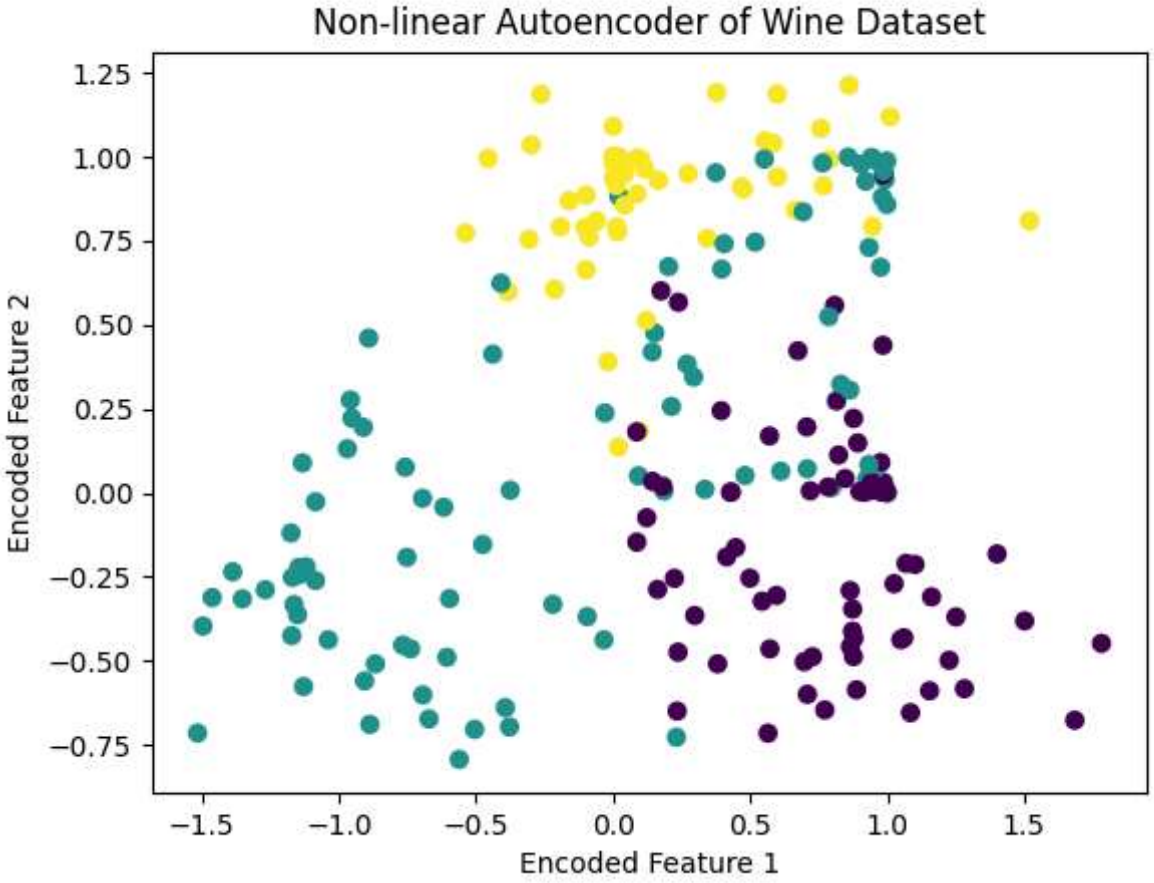
Procedure

1. Implement PCA, Linear Autoencoder and Non-linear Autoencoder
2. Load training data and validation data
3. Train three models one by one
4. Visuallize the outputs and compute recontruction errors respectively

Results


PCA of Wine Dataset
Principal Component 2
Principal Component 1
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Linear Autoencoder of Wine Dataset
Encoded Feature 2
Encoded Feature 1
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

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Reconstruction Error (PCA): 0.446136043405082
Reconstruction Error (Linear Autoencoder): 0.8253447388138331
Reconstruction Error (Non-linear Autoencoder): 0.8887987181851844
```

Analysis

- After data loading and preprocess, the raw *wine_data* is devided into training sets and testing sets, which is used for model training and reconstruction error evaluation respectively.
- As the outputs shown above, PCA is implemented by NumPy and consider only the first two principal components for dimensionality reduction, which performs the best and earns the smallest reconstruction error.
- The Linear Autoencoder and Non-linear Autoencoder are trained with learning rate of **0.01** and **0.001** correspondingly while training iterations is **80000** for both models. It is obvious that Linear autoencoder performs better than the Non-linear one.